H.E. McCoy PPR-1

OFFICE OF MANNED SPACE FLIGHT PROGRAM DIRECTIVE	M-D MA	1400.018 (Project)	DATE Dec. 9, 1965

APOLLO PROGRAM DIRECTIVE NO. 12

TO: Program Manager, SATURN IB
Program Manager, SATURN V
Program Manager, Engines, MSFC
Program Manager, Apollo Spacecraft, MSC
Program Manager, Apollo Applications, MSC

FROM: DIRECTOR, APOLLO PROGRAM

DIRECTOR, SATURN APOLLO APPLICATIONS PROGRAM

SUBJECT: C-1 Engine Use in the Apollo and Saturn Apollo Applications Programs

ACTION : Apollo Program Managers are to develop plans for use of the C-1 engine in applicable vehicles as detailed in Section 3. These are to be submitted to Director, Apollo Program and Director, Saturn Apollo Applications Program by 1 March 1966.

I. PURPOSE

The purpose of this directive is to:

A. Summarize the significant aspects of the currently approved C-1 development program.

B. Initiate planning pertinent to use of the C-1 Engine in both the main-line Apollo Program and the Apollo Applications Program.

II. SCOPE

A. Saturn Apollo Applications Program

The C-1 engine is to be used in all applications for 100-pound thrust class engines in the Saturn launch vehicles and Apollo spacecraft effective SA 213, SA 516, CSM 116 and LEM 16.

B. Apollo Program

Provisions in the main stream Apollo Program are to be made to employ the C-1 engine as a backup in the event it is required.

III. ACTION AND RESPONSIBILITIES

A. Action Pertinent to Apollo Applications Program

Plans are to be developed for incorporating C-1 engines into Saturn launch vehicles and Apollo spacecraft effective SA 213, SA 516, CSM 116 and LEM 16 for the following applications:

SIVB/IB RCS
SIVB/V RCS and Ullage
CM RCS
SM RCS
LEM RCS.

These plans are to be predicated on the current C-1 engine development schedule (Appendix A) and should include schedule and funding for vehicle changes. In developing these plans tradeoff studies should be conducted to assure that only necessary and reasonable changes are made to launch vehicles and spacecraft to incorporate the new engine. These plans should also establish the constraining go-ahead dates which should include but not be limited to dates for:

1. Decision for tankage or other changes.
2. Vehicle or spacecraft contractor notification to initiate change.
3. Engine contractor order to produce flight engines.

B. Action Pertinent to Apollo Program

Plans are to be developed to permit use of the C-1 engine in the mainstream Apollo Program wherever there are unresolved problems in the 100 lb engine systems identified above. The plans should be directed toward defining the minimum system changes considered essential to facilitate the use of the C-1 engine in this "back-up" capacity and should include assumed schedules and associated funding for vehicle and/or spacecraft changes. The C-1 engine availability is to be predicated on the current C-1 engine development schedule (Appendix A). Flight type C-1 engines verified by margin and systems testing are planned to be available beginning November 1966 to replace an unsatisfactory existing engine at that time. Beginning January 1967 replacement can be accomplished with increased confidence using Qualification C-1 hardware which is planned to be available for delivery approximately 4 months before the qualification test is initiated. Tradeoff studies should be conducted and out of sequence engine installation and off-loading of present tankage should be considered to minimize vehicle changes and expedite early application as a backup.

C. Schedule

The plans and studies together with recommendations are to be submitted to the Directors of the Apollo and Saturn Apollo Applications Programs by March 1, 1966.

D. Responsibilities

1. Program Manager, Saturn IB, MSFC is responsible for the submittal of plans for SIVB/IB RCS applications.

2. Program Manager, Saturn V, MSFC is responsible for the submittal of plans for SIVB/V RCS and ullage applications.

3. Program Manager, Apollo Spacecraft, MSC is responsible for the submittal of plans for the following Apollo uses:

   CM RCS
   SM RCS
   LEM RCS

4. Program Manager, Apollo Applications, MSC is responsible for the submittal of plans for the following Apollo Applications uses:

   Extended CM RCS
   Extended SM RCS
   LEM Derivatives RCS

5. Program Manager, Engines, MSFC is to support Saturn IB, Saturn V, Apollo and Apollo Applications Spacecraft studies and plans as requested by appropriate program managers.

C-1 PROGRAM DESCRIPTION

BACKGROUND AND STATUS

The C-1 engine program was initiated in the second half of 1964 to fulfill three basic requirements: (1) to provide an engine of about 100 lbs thrust as a backup in the event of persistent problems in any of the 5 multi-engine systems presently using 5 different engines in the Apollo spacecraft and Saturn vehicles; (2) to provide a backup engine for Gemini RCS systems; and (3) to improve the reliability and reduce costs in the Apollo Applications Program by utilizing a common engine in the same 5 multi-engine applications.

To fulfill these basic requirements the C-1 engine must be capable of meeting the collective requirements of the following specific applications:

a. Re-entry control for the Apollo Command Module
b. Orbital attitude and maneuvering propulsion for the Gemini Spacecraft
c. Ullage settling for the S-IVB Stage of Saturn V
d. Attitude control for the S-IVB Stages of Saturn IB and Saturn V
e. Service Module and Lunar Excursion Module RCS
f. Apollo Applications Program reaction control engines.

The program is being implemented in three phases: Phase I--Definition; Phase II--Development; Phase III--Production.

Prior to Phase I, seven proposals were evaluated. Two companies (Thiokol and TRW) were selected to independently conduct the Phase I Program. Phase I was initiated on March 5, 1965, and completed on September 5, 1965.

At the conclusion of Phase I, each of the two companies submitted updated proposals. Thiokol Chemical Corporation was selected to conduct Phase II of the program. This phase is scheduled for completion in 21 months as shown in Figure 1.

Phase III, the production phase of the program, is expected to begin during the last half of Phase II.

ORGANIZATION RESPONSIBLE FOR MANAGEMENT

The management of the C-1 Engine Program including performance and interface specifications will be performed by the Engine Program Office, Marshall Space Flight Center in close coordination with other elements of MSFC and appropriate elements of the Manned Spacecraft Center.

ENGINE CONFIGURATION

The C-1 Engine being developed by Reaction Motors Division of Thiokol Chemical Corporation in Denville, New Jersey under Contract NAS8-15486 is a fixed thrust rocket engine designed to operate at vacuum thrust levels of 85 - 100 pounds. This engine is designed to meet attitude control, orbital maneuvering and ullage management requirements imposed by the Apollo spacecraft and the upper stages of the Saturn IB and V vehicles.

The basic engine (Figure 1) consists of either a mechanically linked bipropellant valve or a quad redundant valve, a combination radiation and regeneratively cooled combustion chamber, a vortex injector, and a convergent-divergent combustion chamber liner. Adaption of the basic engine to its possible applications is accomplished by utilizing bolt-on, interchangeable ablative or radiation cooled nozzle extensions and providing propellant orificing provisions so that alternate engine thrust levels may be selected for any desired application.

The design parameters to be used in the development of the C-1 are to design an engine which is capable of meeting any combination of the worst case conditions imposed by any of the various applications in which the engine might be used. This is to be verified by testing the engine to the mission duty cycle that it will see in its particular application plus testing to a duty cycle which is considered to be a most severe duty cyle derived from combination of the worst case conditions of the various mission duty cycles. These duty cycles have been established in RMD Specification No. 1272 and are available on request.

ENGINE SPECIFICATION

The C-1 Engine specification will be controlled by the Manager, Space Engine Project (I-E-S) of the Engine Program Office, Marshall Space Flight Center. This office will supply complete specifications as required. In accordance with NASA document, NPC 500-1, Configuration Management Manual, changes to the engine and specification will be processed by the C-1 Engine Configuration Control Board consisting of representatives of using programs and chaired by the Manager, Space Engine Project (I-E-S), MSFC. The following preliminary specification data is to be used for planning purposes only:

The physical characteristics of the basic engine equipped with a bipropellant valve (excluding nozzle extension) are as follows: 4.00" maximum allowable diameter, 7.00" length measured from top of valve to mounting flange, wet weight 5.0 pounds. (Representative total engine weight: Service Module and LEM -- 6.26 pounds; S-IVB -- 8.6 pounds; Gemini 85-pound OAMS -- 11.9 pounds).

The C-1 Engine will utilize the following propellants:

Propellants:

Oxidizer	Nitrogen Tetroxide (N_2O_4)
Fuel	The engine will operate on either one of two fuels: monomethylhydrazine (MMH) or equal parts by weight of hydrazine and unsymmetrical dimethylhydrazine.

These propellants will be supplied at the following nominal pressures and temperatures for the various applications and fuels.

Application	Nominal Static Pressure
Gemini and Apollo Command Module	295 psia ± 15 psi
Saturn IB and V, S-IVB Stage	197 psia ± 15 psi
Service Module and Lunar Excursion Module	193 psia $^{+9}_{-4}$ psi

Propellants	Nominal Steady State MR*	Nominal Supply Temperature
N_2O_4/MMH	1.6	70°F
N_2O_4/N_2H_4-UDMH	1.6	70°F

The vacuum performance ratings based on 200,000 feet altitude versus standard atmosphere 1962 for the engine operating with propellants supplied at the nominal conditions stated above and the expansion ratios indicated, shall be as follows:

	SM-LEM	S-IVB	CM	GEMINI	AAP
(Expansion Ratio)	60 to 1	21 to 1	8.2 to 1	24 to 1	60 to 1
Thrust	100 ± 5%	100 ± 3%	91 $^{+6\%}_{-0\%}$	100 ± 3%	100 ± 5%
Isp Minimum (sec) Steady Stage	301	285	266	285	301
Minimum Impulse Bit (lb.-sec.)	.4 ± 50%	7.5 ± 10%	2 ± 15%	7.5 ± 10%	.4 ± 50%

* Mixture ratio in the pulse mode may increase up to 2.0 as pulse duration decreases. The specific duty cycle must be considered in sizing tanks for an application.

To satisfy the requirements of the C-1 specification the engine equipped with ablative nozzle extensions must operate in pulsing or steady state mode at the performance levels listed above for a minimum total duration of 755 seconds without the external wall temperature exceeding 600°F. When the engine is equipped with radiation cooled nozzle extensions, the specified total duration is increased to 2,000 seconds with no limit on external wall temperature. The engine will also be required to demonstrate 30,000 starts at a pulse frequency from 2 to 35 cps in accumulating the required on-time.

DEVELOPMENT PROGRAM

To develop the C-1 to the requirements outlined, a 21-month program has been established. This will allow qualification of the C-1 with a 99% reliability at 50% confidence level to be completed in July 1967. Provision has also been made for the delivery of ground test engines to NASA starting in August 1966 for use in systems testing. For additional detail of the development program, see Figure 2.

THIOKOL C-1 BASIC ENGINE

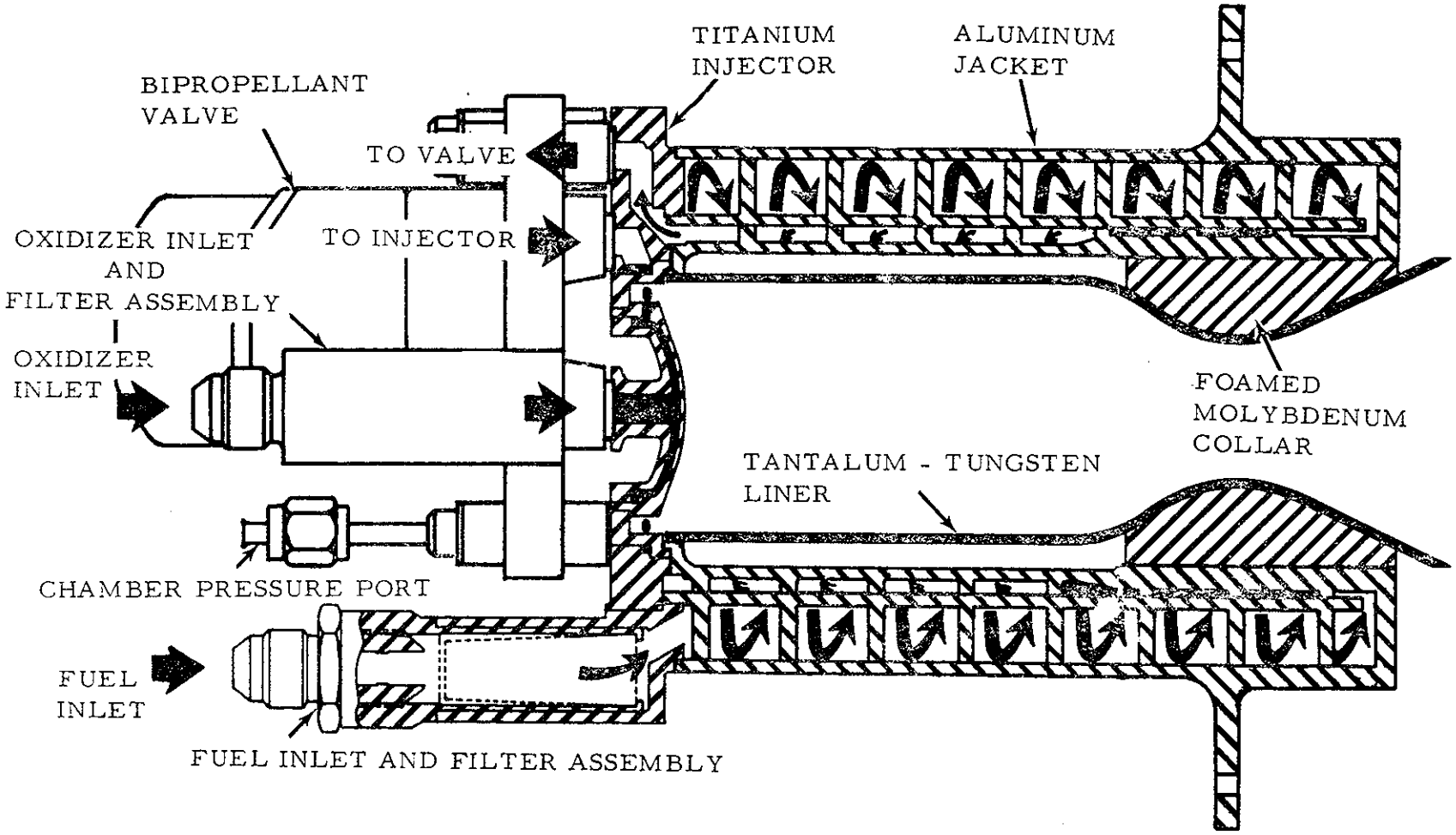
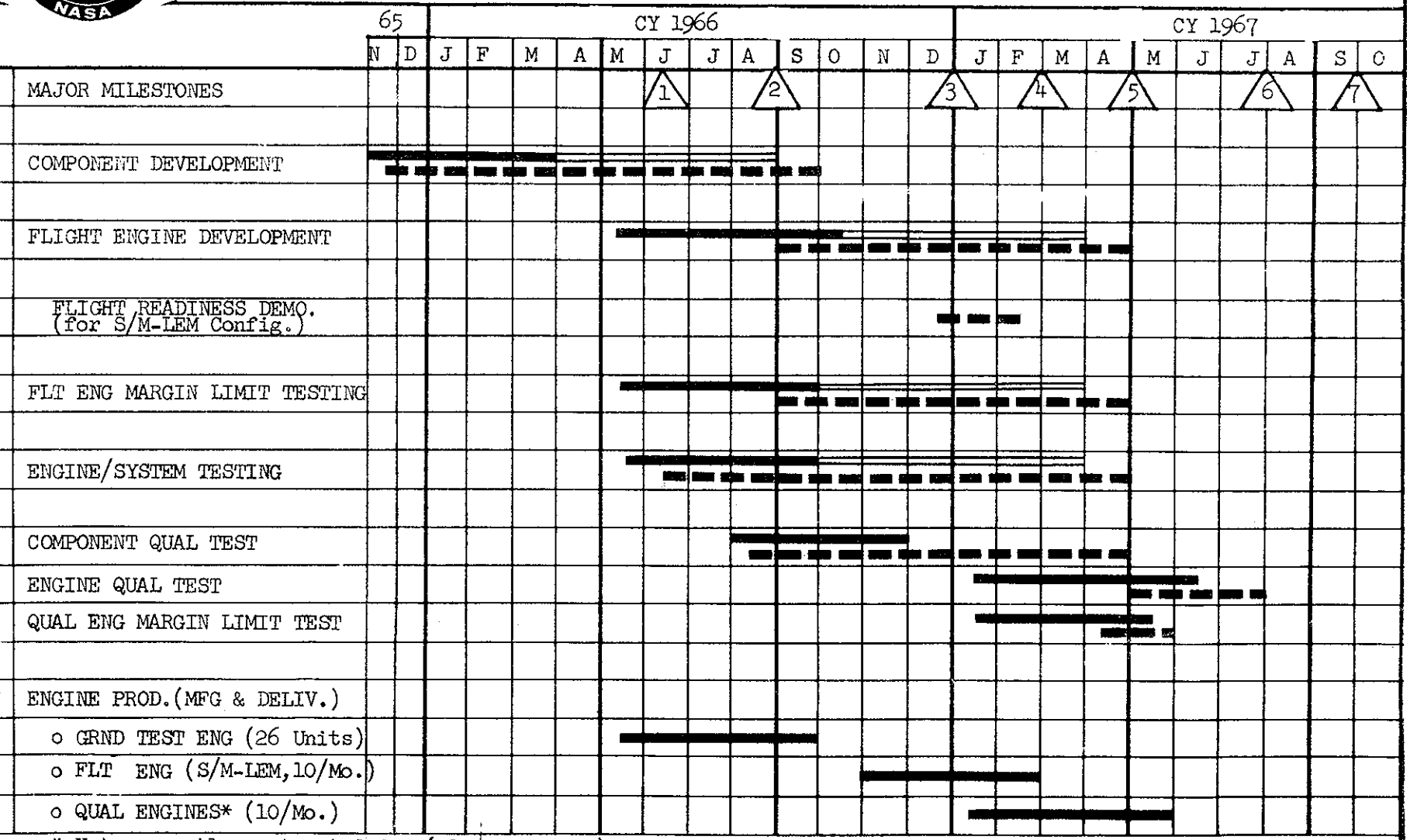


FIGURE 1

I-E-S EPO 1028 OCTOBER 5, 1965

[redacted] ENGINE

PHASE II - PROGRAM MASTER SCHEDULE



NOTES * Not presently contracted for (Planning only)

1 - Flt Eng. Release
2 - 1st Flt Eng to Test
3 - Deliver Prod Pkg
4 - Qual Release
5 - Start Qual Test
6 - Qual Test Complete
7 - Program Complete

Mfg
Refurbish
Dev Test

FIGURE 2

NASA FORM 1169a OCT 64

OFFICE OF MANNED SPACE FLIGHT PROGRAM DIRECTIVE	M - D MA 1400.018 (Project)	DATE Dec. 9, 1965

DISTRIBUTION:

MA/Phillips
MA/Reiffel
MA-1/Schaibley
MA-2/Keegan
MA-3/McGregor
MAO/Holcomb
MAO-1/McClanahan
MAO-2/Abernethy
MAO-3/Stout
MAP/Seccomb
MAP-1/Kubat
MAP-1/Seaton
MAP-1/Skaggs
MAP-1/Hoptay
MAP-1/Crawford
MAP-2/Winn
MAP-2/Dunn
MAP-2/Roth
MAP-3/Waller
MAP-4/Linn (3)
MAP-5/Newman (2)
MAR/Lemke
MAR-R/Willoughby (2)
MAR-Q/Porter
MAR-C/Ragsdale (2)
MAR/Hock
MAS/Thompson
MAS-1/Wagner (3)
MAS-2/Moster (3)
MAS-3/Menard (3)
MAT/Savage
MAT-1/Smith (2)
MAT-2/White (2)
MAT-3/Murad (2)
MAT-4/King (2)
MLT/Wong

M/Mueller
M-1/Bowman
MDM/Bogart
MDP/Jones
MD/Elms
MB/Denicke
MC/Freitag
MCL/Ashley
MG/Schneider (6)
ML/Disher (6)
MP/Lilly (2)
MPP/Rafel (2)
MS/Cotton (4)
MSR/Dry
MPR/Johnson
MF/Coulter (2)
MT/Gray (9)
MO/Christensen (10)
MM/Lovelace (2)
SM/Foster (4)

KSC/Data Manager (34) (V. Gottuso, PA 3)

MSFC/von Braun
MSFC/Mrazek
MSFC/O'Connor
MSFC/James
MSFC/Rudolph
MSFC/Belew
MSFC/Data Manager (95) (R. Goldston, I-RM-M)

MSC/Gilruth
MSC/Shea
MSC/Faget
MSC/Kraft
MSC/Data Manager (60) (C. Knago, PP-2)

OFFICE OF MANNED SPACE FLIGHT PROGRAM DIRECTIVE	M-D MO 2200.042 (Project)	DATE AUG 10 1966

MISSION OPERATIONS DIRECTIVE NO. 12

TO: DISTRIBUTION

FROM:

DIRECTOR, MISSION OPERATIONS

SUBJECT: Mission Operations Plan, Apollo-Saturn 503

REFERENCE:
(a) Apollo Program Development Plan (NPC C500), Section 14, "Mission Operations" (January 1966 new issue)
(b) AS-503 Flight Mission Directive (Prospective)
(c) Apollo Flight Mission Assignments (NPC 500-11), dated 18 March 1966
(d) MO/Director, Mission Operations ltr, dated 6 April 1966, Subj: Reissue of the Schedule for Apollo Operations Documentation
(e) Apollo Program Directive No. 8 (M-D MA 2210.008), dated 8 November 1965, Subj: Apollo Flight Readiness Reviews, Part I
(f) MO/Director, Mission Operations Directive dated 4 August 1965, Subj: Apollo Flight Readiness Reviews, Part II
(g) Apollo Test Requirements, NPC 500-10, dated 20 May 1965
(h) Apollo Mission Failure Contingency Plan dated 13 May 1966

I. AUTHORITY AND PURPOSE. The Apollo-Saturn 503 Mission Operations Plan (MOP) is issued in accordance with reference (a). The purpose of this plan is to prescribe the organization, procedures and documentation required to conduct the AS-503 mission effectively. All preparations for the AS-503 mission will be responsive to and consistent with the MSF AS-503 Flight Mission Directive, reference (b), for technical content and with this plan for operations management. Revisions and/or supplements to this plan will be issued as required.

II. MISSION DESCRIPTION. The AS-503 mission of 8-11 days duration is designed for earth orbital operation of the man configured AS-503 space vehicle. Primary objectives of the mission are to demonstrate launch vehicle capability of inserting a fully loaded Apollo spacecraft on an ellipse employing a nearly full duration S-IVB burn, including S-IVB re-start in orbit; to demonstrate the capability of the Apollo spacecraft, ground support facilities, and crew to perform the LOR mission operations by simulation. Detailed mission objectives and technical requirements are delineated in references (b) and (c).

III. ORGANIZATION.

A. Mission Director: Captain Roderick O. Middleton, USN

B. Other key Operations personnel are as follows:

1. Deputy for Launch Operations (Launch Director): Lt. Col. R. A. Petrone, KSC

2. Mission Operations Manager: Mr. Robert E. Moser, KSC

3. Deputy for Flight Operations: Mr. Christopher C. Kraft, Jr., MSC

4. Flight Director: To be announced

5. DOD Manager for MSF Support Operations: Lieutenant General Leighton I. Davis, USAF, Andrews Air Force Base

6. Medical Director: Mr. Charles A. Berry, MSC

7. Flight Crew Director: Mr. Donald K. Slayton, MSC

8. Public Affairs Officer: Mr. Alfred P. Alibrando, MSF

9. Apollo Flight Operations Representative: Mr. J. K. Holcomb, MSF

10. Apollo Launch Operations Representative: Mr. Fred E. Stout, MSF

11. Requirements Coordinator: Mr. Jack T. McClanahan, MSF

12. Security Officer: Mr. Charles L. Buckley, Jr., KSC

13. Meteorological Officer (Launch-Prelaunch): Mr. Ernest A. Amman, KSC

14. Meteorological Officer (Post launch): Mr. Alan N. Sanderson, MSC

C. All personnel assigned to AS-503 mission operations will render assistance to the Mission Director, through their parent organizations, in order to attain maximum readiness to commence the mission period on schedule and conduct the operation effectively.

IV. DOCUMENTATION. Documentation required for the conduct of AS-503 mission operations, scheduled in reference (d), is as follows:

A. Launch Plan. Director, Kennedy Space Center, is requested to prepare a launch plan in sufficient time to permit coordination with MSC and MSFC as necessary and promulgation and distribution by 1 October 1966. This plan should cover all aspects of launch operations, defining in reasonable detail, the pertinent organization, functions, procedures, and support documentation. It should include but not be restricted to the following:

1. Responsibilities and working relationships for conduct of launch operations, including interfaces with other organizations involved in this mission.

2. Preparation of space vehicle and launch data system checkout plans and countdown procedures.

3. Preparation of test catalogs, test sequence, and test procedures.

4. Preparation of security and safety plans.

5. Preparation of emergency plan.

6. Preparation of public affairs plan.

7. Preparation of post-flight launch complex refurbishment plan.

8. Preparation of KSC assessments for the Flight Readiness Review.

9. Identification of pertinent flight test evaluation and post-launch reports.

10. Schedule for preparation of launch operations documentation, indicating responsibility for preparing and responsibility for approving each document.

B. Flight Operations Plan. Director, Manned Spacecraft Center, is requested to prepare a Flight Operations Plan in sufficient time to permit coordination with MSFC and KSC as necessary, and promulgation and distribution by 1 July 1966. This plan should cover all aspects of flight operations, defining in reasonable detail, the pertinent organization, functions, procedures, and support documentation. It should include but not be restricted to the following:

1. Responsibilities and working relationships for conduct of flight operations, including interfaces with other organizations involved in this mission.

2. Preparation of MCC-H and MSFN checkout plans and procedures.

3. Preparation of flight control procedures and flight plan.

4. Preparation of recovery requirements and coordination procedures with DOD.

5. Preparation of public affairs plan.

6. Definition of training requirements.

7. Preparation of MSC assessments for Flight Readiness Review.

8. Identification of pertinent flight test evaluation and post-launch reports.

9. Schedule for preparation of flight operations documentation, indicating responsibility for preparing and responsibility for approving each document.

C. Mission Rules Guidelines and Mission Rules. AS-503 Mission Rules Guidelines will be prepared and coordinated by the Mission Director for approval by the Associate Administrator for Manned Space Flight (AA/MSF) by 1 April 1967. Pursuant to these guidelines, Director KSC and Director MSC are requested to prepare and distribute Launch Mission Rules and Flight Mission Rules by 1 August 1967. The DOD Manager for Manned Space Flight Support is requested to insure that recovery rules are included in the AS-503 Operation Order. The updated Mission Rules will be reviewed by the Program Director and the Mission Director at the Flight Readiness Review.

D. Mission Support Requirements and Support Plan. Mission support requirements shall be submitted and processed in accordance with the Program Support Requirements Documents (PSRD) Manual of 1 July 1965. Coordination of these requirements and resulting support plans is the responsibility of the Operations Support Requirements Office, MSF. PSRD revisions for AS-503 requirements will be distributed to supporting agencies by 1 June 1967. Support plans in response to these requirements will be prepared in sufficient time for approval and distribution by 1 July 1967.

V. PROCEDURES.

A. Procedures for the conduct of the AS-503 mission will be generally in accordance with the foregoing plans and documents.

B. The Flight Readiness Review (FRR) will be scheduled by separate correspondence to be convened at KSC approximately three weeks prior to launch. Participants and assessments anticipated for this review are summarized in references (e) and (f). A detailed agenda for the FRR will be distributed with the scheduling of the review.

C. Post-flight test report requirements are defined in reference (g). Additional reports, such as quick-look report, may be requested by the Mission Director at his discretion.

D. Procedures for investigating and reporting on any casualty resulting in premature or unsuccessful termination of the AS-503 mission are outlined in the Apollo Mission Failure Contingency Plan, reference (h).

DISTRIBUTION:
See attached sheet

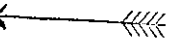
AS-503
OPERATIONS DOCUMENTATION SCHEDULE

	1966						1967									
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O
1. FLIGHT OPERATIONS PLAN	7/1															
2. LAUNCH PLAN				10/1												
3. MISSION RULES GUIDELINES										4/1						
4. PSRD (INITIAL)												6/1				
5. FLIGHT PLAN (PRELIMINARY)												6/1				
6. PROGRAM SUPPORT PLAN													7/1			
7. FLIGHT PLAN														8/1		
8. MISSION RULES														8/1		
9. COUNTDOWN														8/1		
10. NOD SUPPLEMENT														8/1		
11. PSRD (FINAL)															9/1	
12. FRR ASSESSMENT															9/1	

DISTRIBUTION:

MSC
Attn: Director
Manager, Apollo Spacecraft Program Office (6)
Office of Program Managers/Piland
Director of Medical Research Operations (4)
Assistant Director, Flight Operations (6)
Assistant Director, Crew Operations (6)
Landing and Recovery Division/Thompson

MSFC
Attn: Director
Program Managers (6)
Mission Operations Manager (6)

KSC
Attn: Director
Director, Launch Operations (6)
Director, Plans, Programs and Resources (6) 
Assistant Director, Support Operations (6)
Assistant Director, Launch Vehicle Operations (6)
Security Officer

GSFC
Attn: Director, Office of Tracking and Data Systems
Chief, Network Engineering & Operations Division
Chief, Manned Flight Operations Division
Chief, Manned Flight Support Office

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California
Attn: Director
Assistant Director for Tracking and Data Acquisition

National Range Division Headquarters
Andrews Air Force Base, Washington, D.C.
Attn: General L. I. Davis, USAF

Commander, Air Force Eastern Test Range
Patrick Air Force Base, Florida
Attn: Major General V. G. Huston

DISTRIBUTION (CONT'D)

DOD Manager for Manned Space Flight Support Operations
Patrick Air Force Base, Florida
Attn: Colonel R. Olson

U. S. Weather Bureau
Suitland, Maryland
Attn: Spaceflight Meteorology Group

Bellcomm, Inc.
1100 Seventeenth Street, N.W.
Washington, D.C.
Attn: Information Analysis Department Head

NASA Headquarters
Washington, D.C.
Attn: M/Mueller
M-N/Alibrando
MA/Phillips
MT/Gray
MO/Lee, Bolender, Schneider, Middleton, Brown
McElmurry, Miller
T/Buckley
SM/Foster
MAS/Thompson (4)
MAT/Day (4)
MAP/Seccomb
MAR/Lemke (4)
MAO/Holcomb (4)
MC/Freitag
MP/Lilly
MS/Cotton
MB/Armstrong
MM/Bollerud
MG/Day
MSR-3/Davis